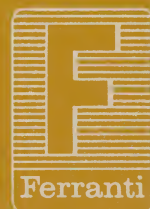


Ferranti

magnetostrictive

DELAY
LINES



Ferranti ELECTRIC, INC. Light Equipment Division

INDUSTRIAL PARK NO. 1 • PLAINVIEW, LONG ISLAND, NEW YORK



Ferranti magnetostrictive DELAY LINES

THE "A-B-C's" OF MAGNETOSTRICTIVE DELAY LINES.

INTRODUCTION

This set of notes is intended to provide general information on Magnetostrictive Delay Lines and to give the prospective user a working understanding of these devices.

Delay lines have been in use now for several years. They are no longer considered a state of the art device. Sound engineering and experience are the only requisites for manufacturing a reliable unit. Ferranti has both, plus a patent on the torsional line.

For the application of delay lines in systems refer to Ferranti application notes as most of the information covered in this paper is basic in nature.

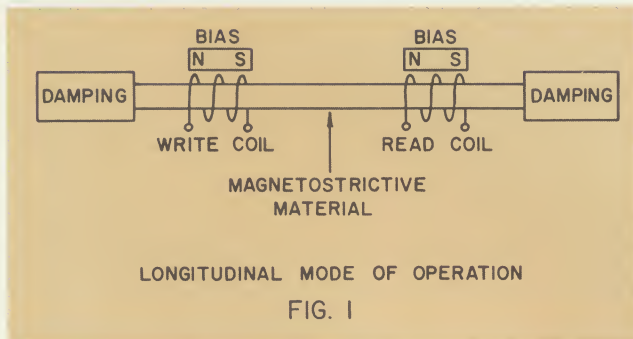
Should you require further specifics beyond the scope of these notes Ferranti will gladly send an applications engineer to discuss your particular delay line problem.

MODES OF OPERATION

The two types of transmission currently used in our Magnetostrictive Delay Lines are longitudinal, and torsional.

A. Longitudinal

The longitudinal mode was the first type discovered, and lends itself to the simplest construction. As seen in Fig. 1 the longitudinal line utilizes an input transducer through which the magnetostrictive material is placed. A current pulse in the input transducer causes the magnetostrictive material to change dimensions, launching a change or stress wave which is transmitted down the line acoustically. This acoustical stress wave changes the μ of the magnetostrictive material and generates a voltage as it passes through the output transducer.

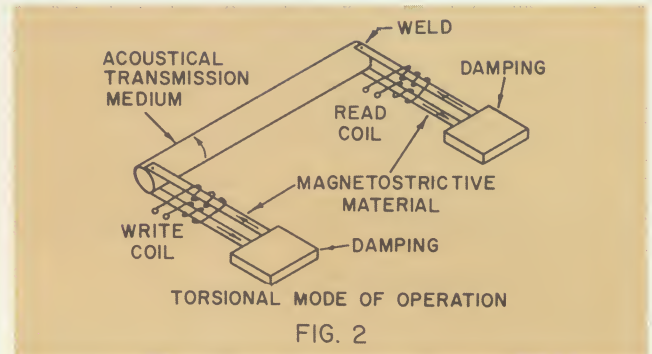


This type of construction makes the line ideal when multiple taps are required. It is also an inexpensive way to construct short untapped lines. Ferranti is capable of producing lines of this type with delays of up to 70 μ sec and center frequencies up to 5mc. The low efficiency of the transducer is an advantage when taps are required. The amount of energy taken by the taps does not effect the acoustical pulse seen by subsequent transducers and identical outputs are obtained from all taps subject to variation due to the increasing attenuation (3db per millisecond at 1 mc).

B. Torsional

As can be seen in Fig. 2, the torsional mode is quite different from the longitudinal mode. When the wave reaches the delay wire, a twisting effect takes place. One of the tapes is welded to the top of the wire, the other to the bottom. When the pulse is launched from one

of the coils, one tape contracts while the other expands, thereby causing a torsional wave to travel along down the acoustical media.

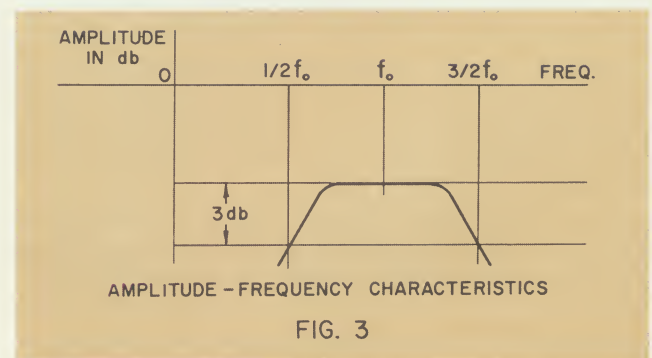


The torsional line has several advantages, one of which is a lower rate of propagation. Longer delays can therefore be obtained, and phase distortion is greatly reduced allowing the line to be used at high frequencies.

By combining both modes in the same delay line, and using high efficiency mode converter transducers, the most desirable capabilities of both types are utilized. This arrangement is used in all untapped Ferranti lines. As mentioned previously, the torsional mode is patented by Ferranti. The material acting as the acoustical media or wave guide need not be magnetostrictive. (See Fig. 2) This material is chosen for a low delay temperature coefficient, and its good acoustical transmission characteristics. A great deal of work has been done by Ferranti in this materials field enabling us to produce acoustical transmission wire having the same delay coefficient in production quantities.

TRANSMISSION CHARACTERISTICS

An ideal line would have a bandpass characteristic as shown in Fig. 3. It must be noted that this drawing has a normalized amplitude characteristic. The insertion loss is not shown. Another characteristic which should be noted, particularly in analog operation, is the flatness of the response. The delay line response will vary approximately 1/2db from the center amplitude response in a frequency approximately 1/3 either side of the center frequency.



With a center frequency of f_0 , a magnetostrictive delay line has a bandwidth of f_0 , 3db points occurring at $1/2f_0$ and $3/2f_0$. This holds true for most delay lines operating in a range 100-700kc center frequency. For lines above this frequency and up to the 5mc range, the fall-off point can be between 3 and 6 db.



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A figure of merit which is used in evaluating a delay line is the delay bandwidth product for which the phase and amplitude characteristics approach the ideal. By proper design practical delay lines approach these ideal characteristics for delay bandwidth products up to 20,000 at the present time, with a target of 30,000 quite possible in the near future. These lines can be used for either analog or digital applications.

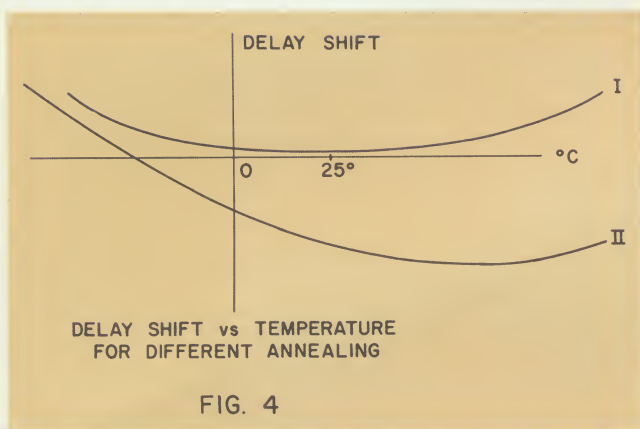
The value of a center frequency f_0 is basically a function of transducer design and in particular its effective magnetic length. This is different from the geometrical length because of flux linkages at the end of the coil.

TEMPERATURE CHARACTERISTICS

The most common method of specifying temperature variations in delay lines as a function of delay shift and temperature is to use the coefficient of delay is specified in ppm/C°. This relation is defined as:

$$T_c = \frac{\text{Delay Shift} \times 10^6}{\text{Total Delay} \times \text{Temperature Range in } ^\circ\text{C}}$$

Two typical curves are shown in Fig. 4. From these curves it can be ascertained that the temperature coefficient in ppm/C° is non-linear throughout the curve. Note, too, that the slopes become larger at extremes of temperature.



It is therefore necessary that the delay variations in such delay lines be specified as the total allowable shift from the nominal delay over the temperature range.

TEMPERATURE COEFFICIENT OF AMPLITUDE

The amplitude coefficient is generally most important in trigger applications since a change in amplitude can cause an effective change in delay. If the requirements are known, lines can be designed in which the amplitude and delay coefficients are compensatory and the effective change in delay over the range —55°C to 125°C can be held to less than 1ppm/C°.

In digital applications the changes in amplitude are not sufficiently great to be troublesome. Careful choice of materials used for delay lines prevents variation of signal to noise ratio with temperature.

IMPEDANCES

Input and output impedances can be designed to suit circuit requirements. By utilizing transistor circuitry, it has been found that the input transducer impedance should be about 150 ohm with capacitance less than 50 pf. Output transducers are designed for use with a 3.3K ohms load, capacitance less than 30 pf. These transducers are, therefore, regarded as standard and supplied unless otherwise specified.

SIGNAL TO NOISE CRITERIA

Static noise is measured by observing the voltage amplitude ratio between the output due to a single input pulse, and voltage amplitude due to the acoustical and electrical noise generated by the input within the line. It is a useful measure of the effectiveness of the line terminations and complete soundness of the welds.

Dynamic noise is measured by circulating a complex pattern through the line with a constant input amplitude and then observing noise appearing at the output in relation to the smallest amplitude output pulse. The dynamic signal-to-noise ratio is usually 1/3 the static signal-to-noise. This is due to the effect of in phase and out of phase reflections which both add and subtract from the signal.

DELAY ADJUSTMENT

A noteworthy feature of Ferranti magnetostrictive delay lines is their incorporation of a delay adjustment. This adjustment of total delay is of the vernier type and normally has a range of $\pm 2 \mu\text{sec}$ from the specific nominal delay. One turn of the adjusting screw changes the delay 125 nanoseconds and makes adjustments of the order of 20 nanoseconds easily obtainable.

TAPS

There are two methods of tapping a delay line. The first method is achieved by welding a magnetostrictive tape to a specific point on the delay line. This type of tap will draw energy from a delay line and therefore limits the number of taps which can be attached to the line. The maximum number of taps in this case is usually four. This tapping method introduces reflections thereby reducing the signal-to-noise ratio of the overall unit. This method of tapping can be accomplished on all Ferranti torsional lines.

The other method of tapping utilizes what is known as the Weideman effect. Here a transducer is attached directly to the acoustical media. The media is biased with transverse electric field or a coaxial magnetic field. The acoustical disturbance at the point of the transducer causes a change in the μ of the material, thereby inducing a voltage.

This type of tap does not draw any energy from the delay line, therefore, the number of taps is limited only by the mechanical distance which these taps may be spaced from each other. Ferranti has made these types of lines with over 300 taps. It must be noted that the L20 type delay line, a longitudinal device, uses this type of specific tapping, although here a coaxial magnetic field is set up with a permanent magnet. Again in this particular type of line the taps are limited only by physical dimensions.

ENVIRONMENTAL & SPECIAL PACKAGING

Ferranti delay lines can be supplied to suit either military or commercial environmental requirements. Having no moving parts the delay lines are inherently rugged. Standard packages to suit many environmental conditions are available as fully engineered products on short delivery. Lines to any one of a wide range of delays, and any specified center frequency within the specifications stated by Ferranti, can be supplied using these packages. Where required environment or package specifications cannot be met with existing packages, the standard sizes may often be used for initial engineering models and enable work to proceed during the development of a special package. Ferranti has produced many special packaged delay lines in the past and many of these lines are listed and described in our catalog. Some of these units are continuously variable delay lines with a great many taps, while some delay lines meet all military environment conditions, including shock, vibration, temperature, humidity, etc.



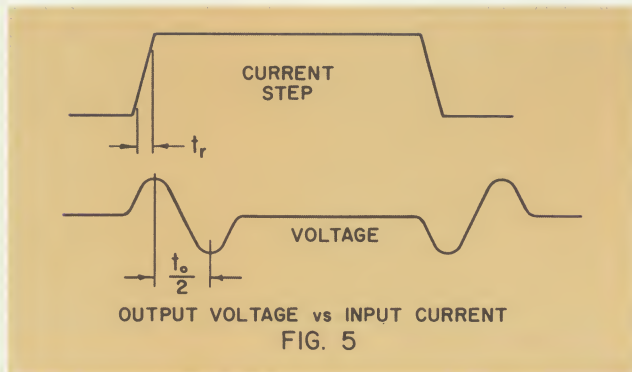
Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES

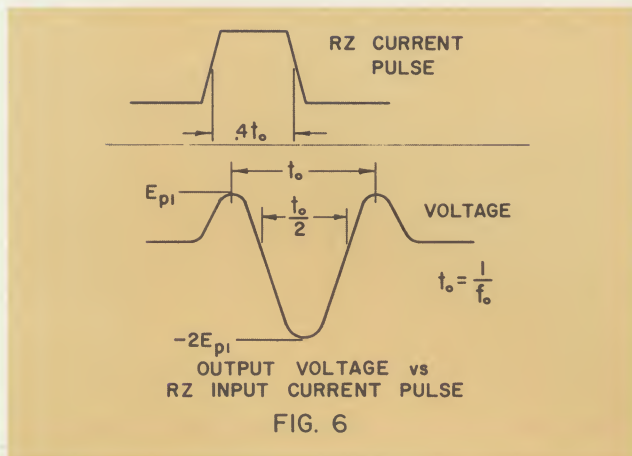
RECORDING TECHNIQUES

Output Waveshape

The output voltage pulse from a delay line is, to a first approximation, the second derivative of the input current wave form. Thus, a step of current in the input coil will produce an output wave form as shown in Fig. 5, where the time duration between positive and negative peaks of the dipole is $t_0/2$.



The voltage at the receive transducer for a pulse is shown in Fig. 6. This may be understood by combining two dipoles of step current where the positive peak is twice the amplitude of either of the negative peaks. It should also be noted that when the transducers are properly designed and terminated the average voltage is zero. A first approximation for the output wave shape is $\frac{\sin x}{x}$.



RETURN TO ZERO RECORDING OR RZ

The most common method of recording digital information is to represent a "one" by a pulse and a "zero" by the absence of a pulse. This is called a return to zero or RZ method, because the current returns to zero between successive bits of information. The maximum bit rate at which the delay line should be used in order to provide adequate operating margins is equal to the bandwidth of the line or the center frequency f_0 .

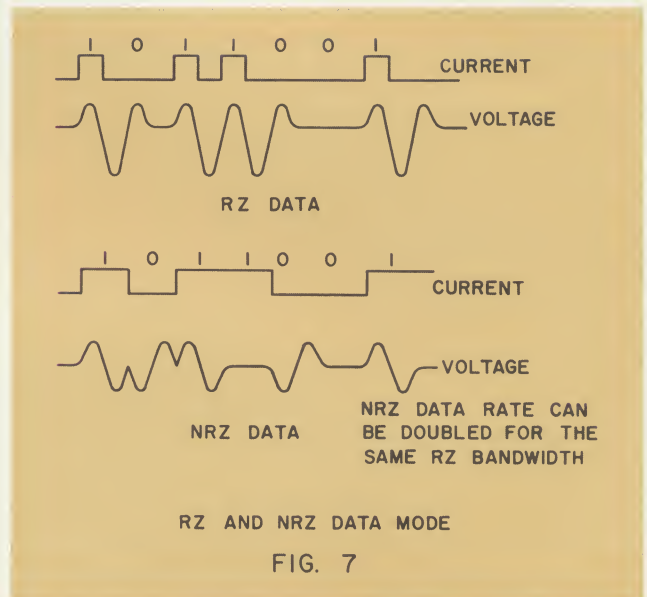
This corresponds to a minimum spacing between bits of "1". The width of the input pulse should not exceed $0.5f_0$ and generally $0.4f_0$ or less will yield a greater operating tolerance. A typical input pattern for standard RZ recording is shown in Fig. 6 together with the output wave form from the delay line. No time delay is shown for the sake of

clarity. The rise time of t_r of the current pulse should be in the range of $0.1t_0$ to $0.15t_0$ where $t_0 = 1/f_0$.

If the delay line is being used for storage purposes, it is necessary to amplify the line output and reset it for both time and amplitude before recirculation. Amplification is conventional, the only requirements being to provide sufficient signal and bandwidth to drive a retiming gate. Several methods are available for retiming, the choice depending mainly on the ease with which the delay line characteristics of the line can be obtained. If the delay line can be readily made to have a delay drift of less than $\pm 0.1 \mu\text{sec}$ over the required temperature range, the simplest and most economical method of retiming is to "and" the output of the linear amplifier with a strobe clock having a pulse duration in the order of $0.1t_0$.

NON-RETURN TO ZERO OR NRZ

NRZ logic system defines a "one" at a voltage level different than that of a "zero" voltage level. The difference with respect to RZ is that each "one" is not a discrete pulse but is represented only by a level change. A string of "ones" will be represented by suitable pulse with duration equal to the aggregate duration of the "ones". The string of "zeros" will still be represented by the absence of data in the delay line (see Fig. 7).



BI-POLAR AND TERNARY

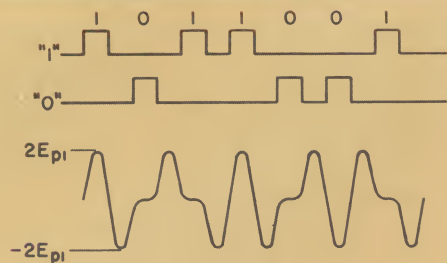
These two modes are really very similar, a "one" and a "zero" are written in opposite polarities. Current is thus normally always flowing in the transducer in one direction or the other, (see Fig. 8). The ternary mode might be described as a binary plus space. It is possible to think of spaces as the end of a word or the end of a message marker, which can readily be restored but which do not require recording. Thus they can in some applications greatly simplify the control requirements.

The bi-polar method, which is sometimes called the Ferranti or Manchester method of recording, has great advantages in systems where shock and vibration are dominant factors of the environmental conditions. Ferranti has tested this particular type of amplifier system and has developed it to a point where almost a one to one signal-to-noise ratio is allowed without any errors being caused in the output of the delay line.



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BI-POLAR DATA MODE

FIG. 8

GLOSSARY OF MDL

1) Impedance

- a Source impedance—impedance of a pulse source as seen by the delay line input terminals.
- b Terminating impedance—impedance load as seen by the delay line output terminals.
- c Input impedance—impedance seen looking into the delay line input terminals.
- d Output impedance—impedance seen looking back into the delay line at the output terminals.

2) Pulse Amplitude Output

The values of the first and second peaks of the voltage doublet E_{p1} and E_{p2} of Fig. 9, resulting from input step of current.

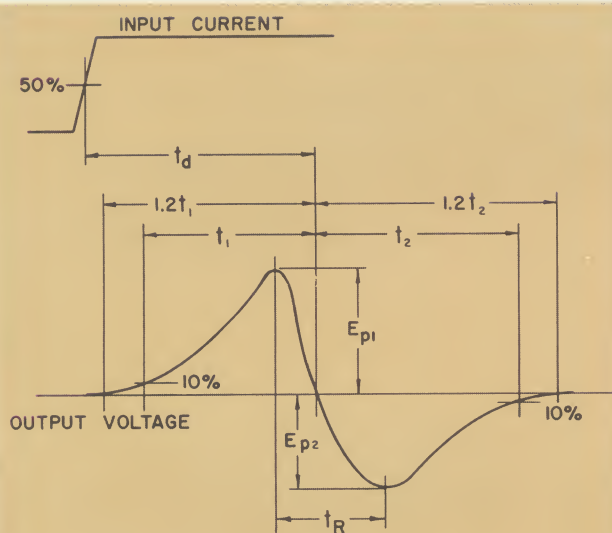


FIG. 9

3) Input Power

The power expended in driving the delay line.

4) Output Power

The power dissipated in the resistive component of the terminating network.

5) Delay Line Attenuation

A ratio of input power to output power in db.

6) Temperature Variation (Delay and Amplitude)

The change in delay over a specified temperature range. The change in amplitude of the output pulse over a specified temperature range.

7) Pulse Duration

The time from the 10% value of the first portion of the output doublet to the zero crossing t_1 , or the time from the zero crossing to the 10% value of the second portion of the output doublet t_2 . (See Fig. 9)

8) Delay Time

The duration of time from the 50% value of the leading edge of the input current step to the zero crossing of the output doublet t_2 . (See Fig. 9)

9) Resolution

The time spacing between E_{p1} and E_{p2} . (See Fig. 9)

10) Noise

Any peak response across the output terminals outside the time covered by $1.2t_1$ and $1.2t_2$. (See Fig. 9). The output response will be designated E_N .

11) Signal To Noise Ratio

The ratio of either E_{p1} or E_{p2} to E_N .

MDL MEASUREMENTS

- a Source and terminating impedance measurements shall be taken at frequencies whose period is 2 times t_R .
- b Terminating impedance is the parallel combination of C_2 and R_2 (See Fig. 10) at the frequency whose period is $2t_R$ and shall include the impedance of the measuring equipment.

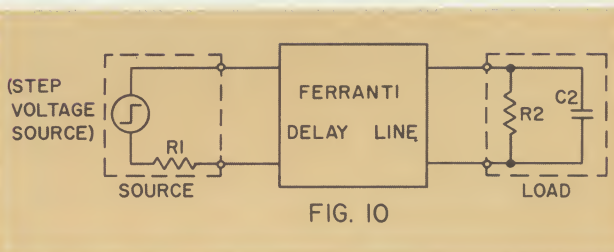


FIG. 10

- c Current input step to have a rise time of no greater than $0.15t_R$.
- d The input power is I^2R where I is the amplitude of the input current step.
- e Output pulse is to be measured by an oscilloscope placed across R_2 to observe the result directly.
- f Output power is given as $(E_{p1})^2$ divided by R_2 or $(E_{p2})^2$ divided by R_2 as specified.

INTEGRATED AMPLIFIER SYSTEMS

Ferranti is now supplying integrated delay line systems off the shelf and to customer specifications. With an integrated amplifier the customer has only to concern himself with a pulse-in, delayed-pulse-out type system. Amplifiers are available in all modes of operation; RZ and NRZ, Bi-Polar and NRZ Bi-Polar. The amplifiers are available in both clocked and unclocked version.

For further information on Ferranti integrated systems, see the application notes on the amplifiers and delay line systems, and also the data sheets on Ferranti delay line amplifiers.



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magnetostrictive DELAY LINES

Patent No. 2401094 • Made in USA



DELAY RANGE: 5.0-20 μ sec

Ferranti

L20-1

PULSE WIDTH: 0.10-1.6 μ sec
(specify when ordering)

DESCRIPTION

The L20-1 is a fixed delay line with a fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

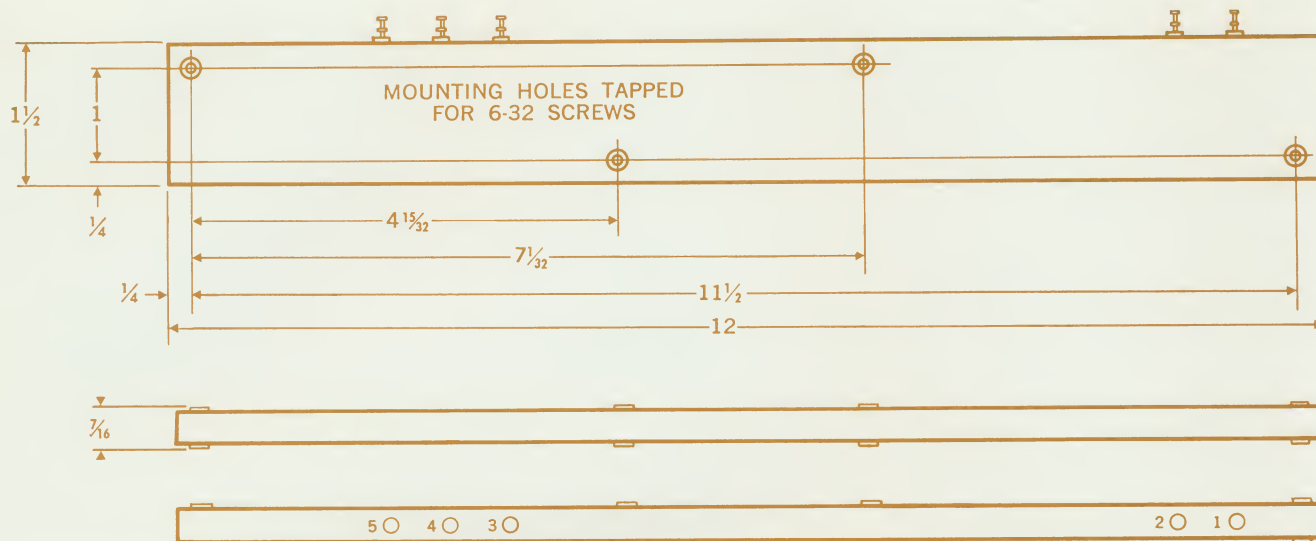
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 5.0mc
MAXIMUM BAND WIDTH	5.0mc
MAXIMUM STORAGE CAPACITY	RZ 100 bits NRZ 200 bits



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TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —150 ohms Z_o —450 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	45db
Input Drive	20ma
Output Voltage (into a 3.3K load)	25mv
Static Signal/Noise Ratio	20:1
Dynamic Signal/Noise Ratio	7:1
Delay Drift	$\pm 0.03 \mu\text{sec}$
Digit Rate	RZ: up to 5.0mc NRZ: up to 10.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 6 oz.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

Taps can be provided subject to a minimum tap spacing of 1 μsec , except for the delay between the drive transducer and the first tap which may not be less than 2 μsec . The taps are adjustable over a small range. This is accomplished by loosening a set screw located on the underside of the package, and adjusting the tap. This unit is also available as a continuously variable delay line.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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Patent No. 2401094 • Made in USA



DELAY RANGE: 20-50 μ sec

Ferranti

L20-2

PULSE WIDTH: 0.10-1.6 μ sec
(specify when ordering)

DESCRIPTION

The L20-2 is a fixed delay line with a fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

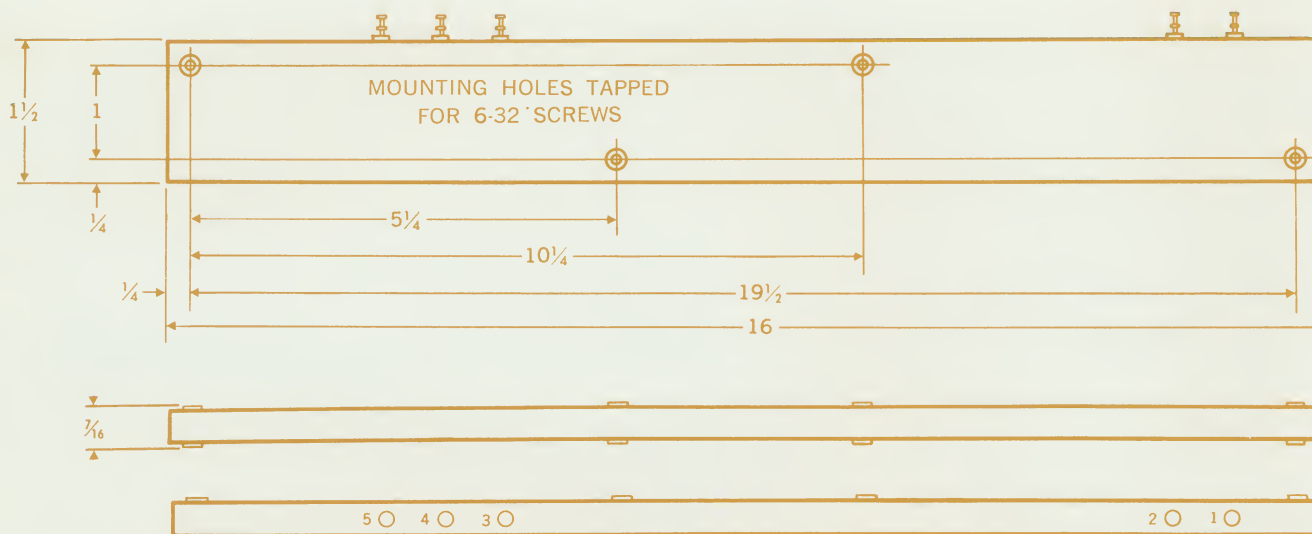
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 5.0mc
MAXIMUM BAND WIDTH	5.0mc
MAXIMUM STORAGE CAPACITY	RZ 250 blts NRZ 500 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —150 ohms Z_o —450 ohms
Delay Adjustment Range (± 2 μ sec from specified delay)	4 μ sec
Insertion Loss (max)	45db
Input Drive	20ma
Output Voltage (into a 3.3K load)	25mv
Static Signal/Noise Ratio	20:1
Dynamic Signal/Noise Ratio	7:1
Delay Drift	± 0.07 μ sec
Digit Rate	RZ: up to 5.0mc NRZ: up to 10.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 7 oz.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

Taps can be provided subject to a minimum tap spacing of 1 μ sec, except for the delay between the drive transducer and the first tap which may not be less than 2 μ sec. The taps are adjustable over a small range. This is accomplished by loosening a set screw located on the underside of the package, and adjusting the tap. This unit is also available as a continuously variable delay line.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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Patent No. 2401094 • Made in USA



DELAY RANGE: 50-70 μ sec

Ferranti

L20-3

PULSE WIDTH: 0.10-1.6 μ sec
(specify when ordering)

DESCRIPTION

The L20-3 is a fixed line with a fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

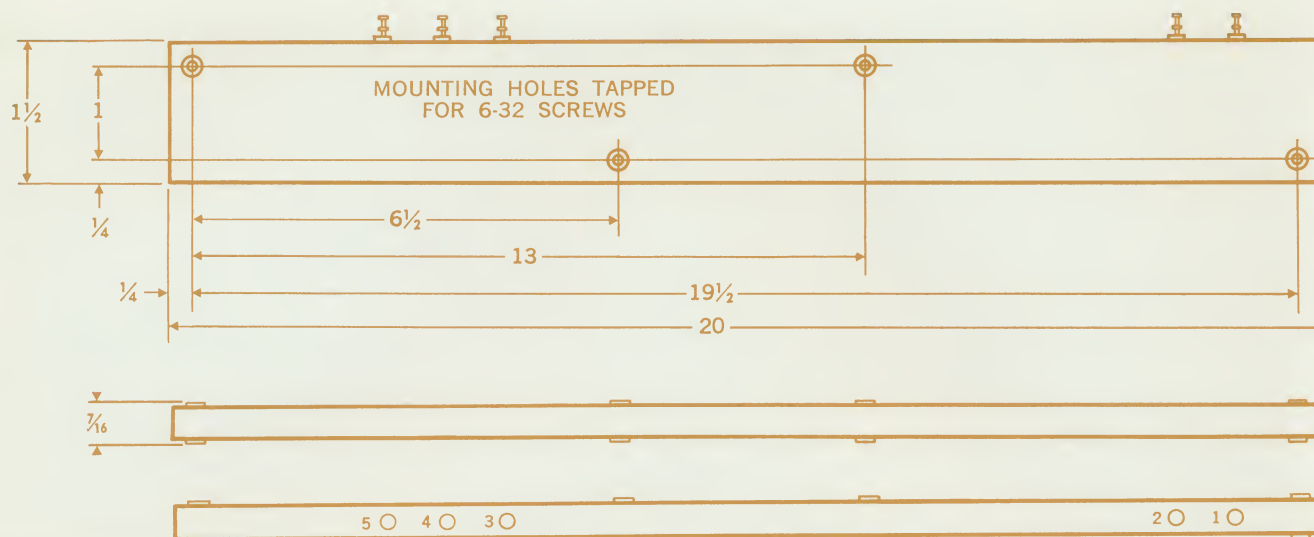
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 5.0mc
MAXIMUM BAND WIDTH	5.0mc
MAXIMUM STORAGE CAPACITY	RZ 350 bits NRZ 700 bits



Ferranti ELECTRIC, INC. Light Equipment Division

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TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —150 ohms Z_o —450 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	45db
Input Drive	20ma
Output Voltage (into a 3.3K load)	25mv
Static Signal/Noise Ratio	20:1
Dynamic Signal/Noise Ratio	7:1
Delay Drift	$\pm 0.1 \mu\text{sec}$
Digit Rate	RZ: up to 5.0mc NRZ: up to 10.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 8 oz.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

Taps can be provided subject to a minimum tap spacing of 1 μsec , except for the delay between the drive transducer and the first tap which may not be less than 2 μsec . The taps are adjustable over a small range. This is accomplished by loosening a set screw located on the underside of the package, and adjusting the tap. This unit is also available as a continuously variable delay line.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 20-250 μ sec

Ferranti

L25

PULSE WIDTH: 0.25-1.6 μ sec
(specify when ordering)

DESCRIPTION

The L25 is a fixed delay line with a fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

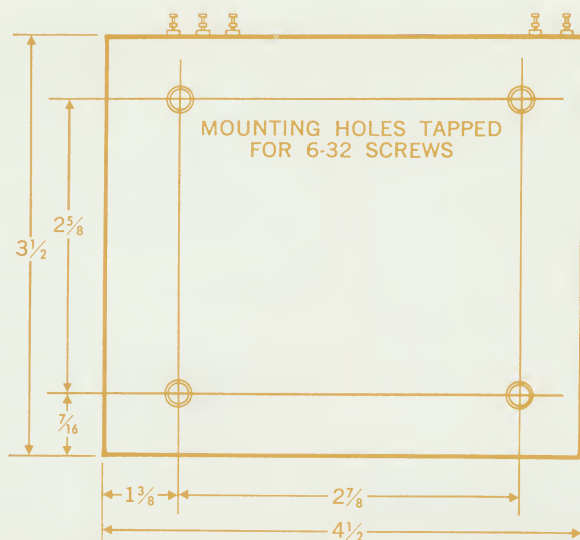
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 2.0mc
MAXIMUM BAND WIDTH	2.0mc
MAXIMUM STORAGE CAPACITY	RZ 500 bits NRZ 1,000 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —150 ohms Z_o —450 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	47db
Input Drive	20ma
Output Voltage (into a 3.3K load)	20mv
Static Signal/Noise Ratio	20:1
Dynamic Signal/Noise Ratio	7:1
Delay Drift	$\pm 0.08 \mu\text{sec}$
Digit Rate	RZ: up to 2.0mc NRZ: up to 4.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 6 oz.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

The L25 is not available in a tapped version.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 250-850 μ sec

Ferranti

L30

PULSE WIDTH: 0.35-1.6 μ sec
(specify when ordering)

DESCRIPTION

The L30 is a fixed delay line with a fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

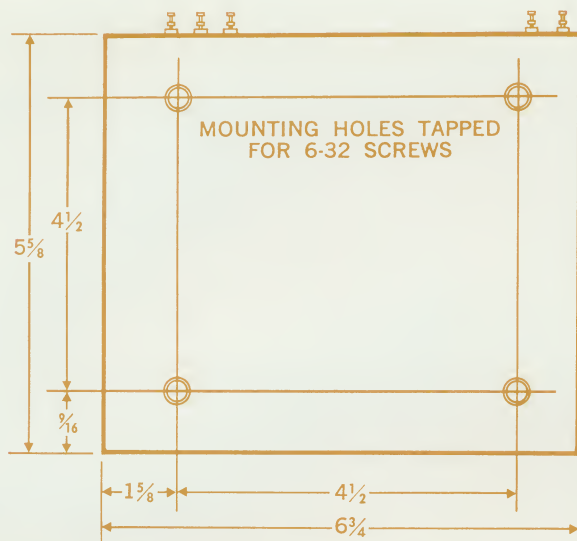
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 1.5mc
MAXIMUM BAND WIDTH	1.5mc
MAXIMUM STORAGE CAPACITY	RZ 1,300 bits NRZ 2,600 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —150 ohms Z_o —450 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	48db
Input Drive	20ma
Output Voltage (into a 3.3K load)	20mv
Static Signal/Noise Ratio	20:1
Dynamic Signal/Noise Ratio	7:1
Delay Drift	$\pm 0.14 \mu\text{sec}$
Digit Rate	RZ: up to 1.5mc NRZ: up to 3.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 8 oz.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

A limited number of taps can be provided. The maximum number is generally two depending on the tap positions required. The taps are adjustable over a normal range of 4 μsec . This adjustment is not normally available to the user except by removal of the cover. The outputs from the taps will be similar to those obtained from the line output.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 850-2500 μ sec

Ferranti

L35

PULSE WIDTH: 0.4-5.0 μ sec
(specify when ordering)

DESCRIPTION

The L35 is a fixed delay line with fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

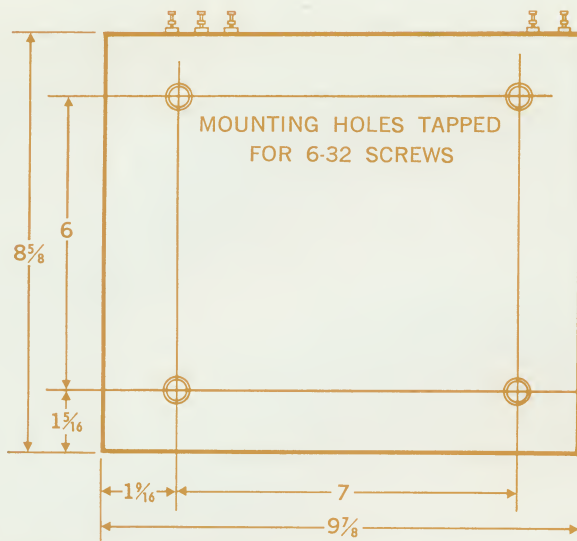
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 1.0mc
MAXIMUM BAND WIDTH	1.0mc
MAXIMUM STORAGE CAPACITY	RZ 2,500 bits NRZ 5,000 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance

Z_i —300 ohms
 Z_o —500 ohms

Delay Adjustment Range
($\pm 2 \mu\text{sec}$ from specified delay)

4 μsec

Insertion Loss (max)

56db

Input Drive

25ma

Output Voltage (into a 3.3K load)

10mv

Static Signal/Noise Ratio

20:1

Dynamic Signal/Noise Ratio

7:1

Delay Drift

$\pm 0.1 \mu\text{sec}$

Digit Rate

RZ: up to 1.0mc
NRZ: up to 2.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 1 lb.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

A limited number of taps can be provided. The maximum number is generally four depending on the tap positions required. The taps are adjustable over a total range of 4.0 μsec . This adjustment is not normally available to the user except by removal of the cover. The outputs from the taps will be similar to those obtained from the line output.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 2500-5000 μ sec

Ferranti

L40

PULSE WIDTH: 0.4-1.6 μ sec
(specify when ordering)

DESCRIPTION

The L40 is a fixed delay line with a fine adjustment, suitable for commercial and certain military environments. Lines to meet all military specifications are available.

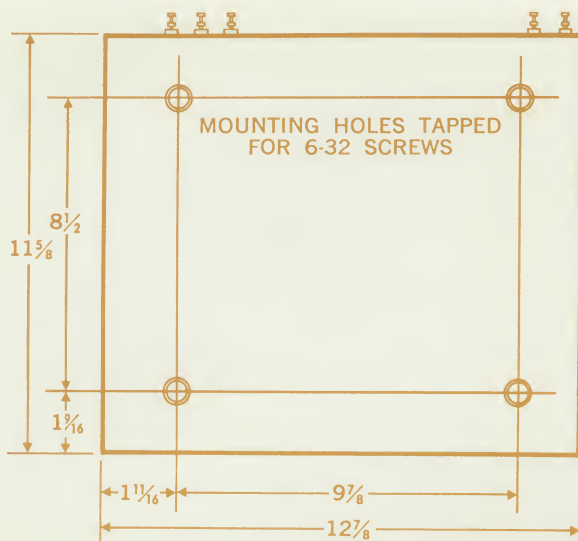
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 1.0mc
MAXIMUM BAND WIDTH	1.0mc
MAXIMUM STORAGE CAPACITY	RZ 5,000 bits NRZ 10,000 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —300 ohms Z_o —500 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	63db
Input Drive	50ma
Output Voltage (into a 3.3K load)	10mv
Static Signal/Noise Ratio	20:1
Dynamic Signal/Noise Ratio	7:1
Delay Drift	$\pm 0.2 \mu\text{sec}$
Digit Rate	RZ: up to 1.0mc NRZ: up to 2.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 2 lbs.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

A limited number of taps can be provided. The maximum number is generally four depending on the tap positions required. The taps are adjustable over a total range of 4 μsec . This adjustment is not normally available to the user except by removal of the cover. The outputs from the taps will be similar to those obtained from the line output.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 5000-10,000 μ sec

Ferranti

L45

PULSE WIDTH: 0.9-2.5 μ sec
(specify when ordering)

DESCRIPTION

The L45 is fixed delay line with a fine adjustment suitable for commercial and less severe military environments. Lines to meet all military specifications are available.

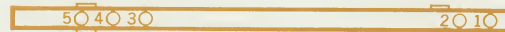
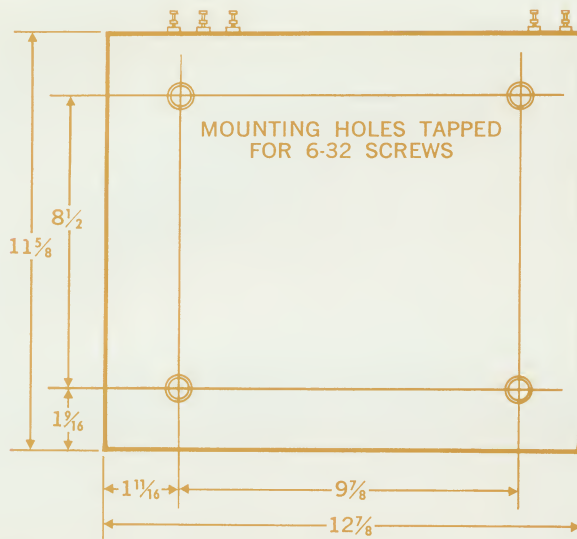
BASIC RATINGS

CENTER FREQUENCY RANGE	200kc to 500kc
MAXIMUM BAND WIDTH	500kc
MAXIMUM STORAGE CAPACITY	RZ 5,000 bits NRZ 10,000 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 500KC

Transducer Impedance	Z_i —300 ohms Z_o —500 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	70db
Input Drive	50ma
Output Voltage (into a 3.3K load)	5mv
Static Signal/Noise Ratio	15:1
Dynamic Signal/Noise Ratio	5:1
Delay Drift	$\pm 0.4 \mu\text{sec}$
Digit Rate	RZ: up to 500kc NRZ: up to 1.0mc

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 2 lbs.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

A limited number of taps can be provided. The maximum number is generally four depending on the tap positions required. The taps are adjustable over a total range of 4 μsec . This adjustment is not normally available to the user except by removal of the cover. The outputs from the taps will be similar to those obtained from the line output.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA (Non-operating)

This unit can meet all environmental conditions of MIL-STD-202B or other military specifications. Additional shock and vibration data are available upon request.

Vibration

Simple harmonic motion in three mutually perpendicular directions for 6 hours, 10 to 55 cps, 0.6 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.



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Patent No. 3011136 • Made in USA

DELAY RANGE: 50-500 μ sec

Ferranti

5811

PULSE WIDTH: 0.4-2.0 μ sec
(specify when ordering)

DESCRIPTION

The 5811 is a fixed delay line with a fine adjustment, suitable for military environments. The line is designed for, and meets military specifications MIL-E-5272A and MIL-T-4807A.

BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 1.0mc
MAXIMUM BAND WIDTH	1.0mc
MAXIMUM STORAGE CAPACITY	RZ 500 bits NRZ 1,000 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 20-2100 μ sec

Ferranti

5912

PULSE WIDTH: 0.4-1.6 μ sec
(specify when ordering)

DESCRIPTION

The 5912 is a fixed delay line with a fine adjustment, designed for military environments. The unit is designed to meet MIL-STD-202B.

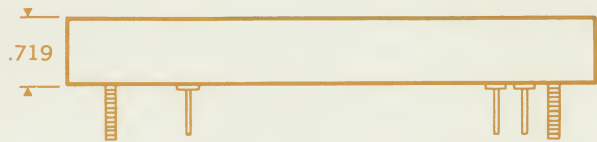
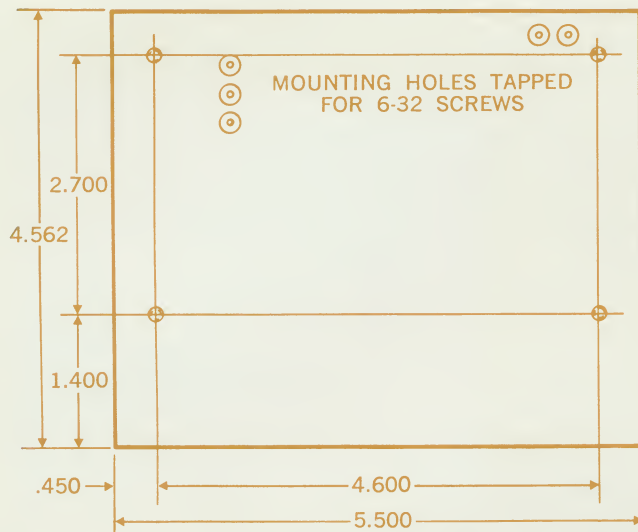
BASIC RATINGS

CENTER FREQUENCY RANGE	300kc to 1.0mc
MAXIMUM BAND WIDTH	1.0mc
MAXIMUM STORAGE CAPACITY	RZ 2,100 bits NRZ 4,200 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 1MC

Transducer Impedance	Z_i —450 ohms Z_o —750 ohms
Delay Adjustment Range (± 2 μ sec from specified delay)	4 μ sec
Insertion Loss (max)	65db
Input Drive	80ma
Output Voltage (into a 3.3K load)	10mv
Static Signal/Noise Ratio	10:1
Dynamic Signal/Noise Ratio	5:1
Delay Drift	± 0.1 μ sec
Digit Rate	RZ: up to 1.0mc NRZ: up to 2.0mc

5912

PHYSICAL RATINGS

The case is a hermetically sealed steel unit.
Dimensions: See dimensional drawing.
Weight: 15 oz.

STANDARD TEMPERATURE RANGE

0-60°C.
Lines to operate from -65°C to 105°C are available on request.

TAPPED LINES

Type 5912 is not available in a tapped version.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.

ENVIRONMENTAL DATA

The 5912 package is specifically designed to meet MIL-STD-202B. The unit is available to meet any military specification.

Type 5912 has been tested to meet the following specifications, non-operating except where indicated:

Temperature

-62°C to 105°C at 50,000 feet.

Humidity

At the conclusion of testing under Method 102A the unit conforms to all electrical specifications.

Vibration

Method 201A. Simple harmonic motion in three mutually perpendicular planes for 6 hours, 10 to 55 cps, 0.03 to 0.06 inch excursion.

Shock

Method 202A, 18 blows at 50g's.

Salt Spray

Method 101A.

Fungus

Not applicable.



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magnetostrictive DELAY LINES



Patent No. 3011136 • Made in USA

DELAY RANGE: 400-16,000 μ sec

Ferranti

6053

PULSE WIDTH: 0.9-5.0 μ sec
(specify when ordering)

DESCRIPTION

The 6053 delay line is designed to provide a fixed delay, with provisions for a large number of taps from which outputs may be taken simultaneously. The unit is designed to meet military ground equipment environmental conditions.

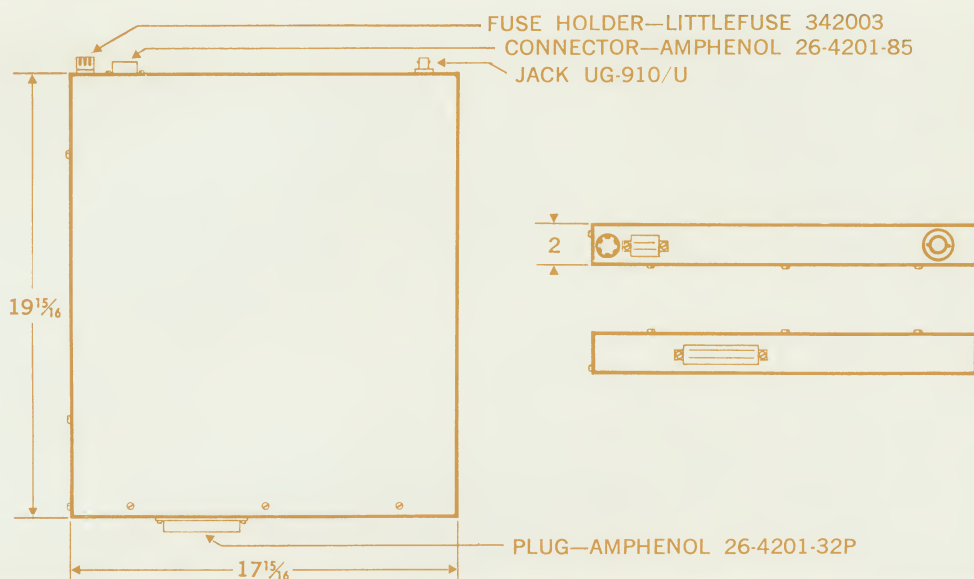
BASIC RATINGS

CENTER FREQUENCY RANGE	100kc to 500kc
MAXIMUM BAND WIDTH	500kc
MAXIMUM STORAGE CAPACITY	RZ 8,000 bits NRZ 16,000 bits



Ferranti ELECTRIC, INC. Light Equipment Division

magnetostrictive DELAY LINES



TYPICAL OPERATING CHARACTERISTICS AT 500KC

Transducer Impedance	Z_i —300 ohms Z_o —500 ohms
Delay Adjustment Range ($\pm 2 \mu\text{sec}$ from specified delay)	4 μsec
Insertion Loss (max)	80db
Input Drive	100ma
Output Voltage (into a 3.3K load)	3.0mv
Static Signal/Noise Ratio	10:1
Dynamic Signal/Noise Ratio	5:1
Delay Drift	$\pm 0.3 \mu\text{sec}$
Digit Rate	RZ: up to 8,000 bits NRZ: up to 16,000 bits
Bias	300ma DC for line with taps

PHYSICAL RATINGS

Anodized aluminum case with aluminum and molded internal parts.

Dimensions: See dimensional drawing.

Weight: 12 lbs.

STANDARD TEMPERATURE RANGE

0-60°C.

Lines to operate from -50°C to 100°C are available on request.

TAPPED LINES

This unit is designed for multiple tap application. A maximum of 300 taps can be put on this line with a minimum spacing of 5.0 μsec , adjustable to 0.1 μsec accuracy, set screw locking provision.

NOTE: See Ferranti amplifier data sheets for compatibility with Ferranti delay lines.

TEST DATA

Test reports covering all performance characteristics and photographs of output wave shapes can be supplied upon customer's request.

ENVIRONMENTAL DATA

This unit is designed to meet military standard 202A and has been tested to the electrical characteristics below.

All specifications are non-operating unless otherwise indicated.

Temperature

-50° to 100°C at 50,000 feet, operating.

Humidity

Method 103A for 360 hours.

Vibration

Method 201A, 5 to 55 cps, 10g's.

Shock

Method 202A, 18 blows at 50g's.



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BUFFER STORE

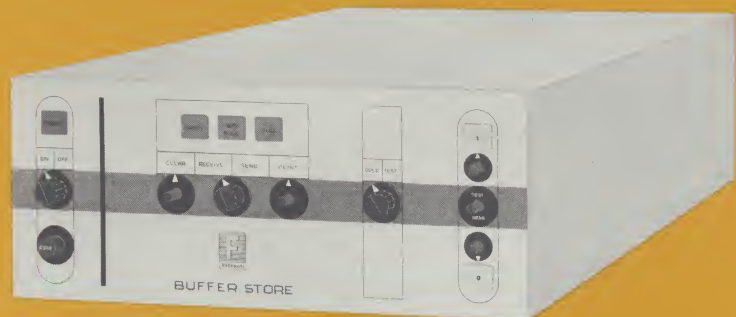
Ferranti

OPERATING MODE

serial or parallel input or output

READOUT

destructive or non-destructive



DESCRIPTION

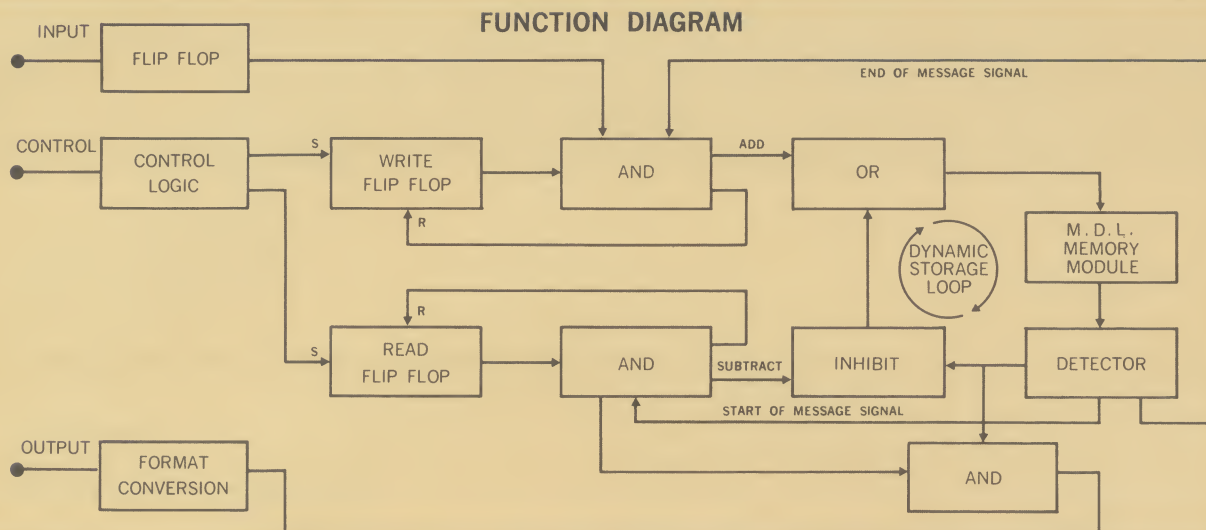
The Ferranti Buffer Store is intended for real time processing of digital information between two or more pieces of digital equipment operating at different time rates. Consequently it is compatible for use with most of the computers, magnetic tapes, paper tape readers, card readers, card punches, typewriters and Teletype machines in operation today. The unit is modularized permitting the storage capacity to be increased or decreased readily, thus affording the user the most economical

design. All logic and control functions are performed through silicon circuitry and are made compatible with germanium logic conventions through the use of auxiliary input and output conversions. A self-contained power supply, an internal test mode, and logic indicators provide for ease of operation with a minimum of personnel training. Magnetostrictive delay lines are utilized as the timing and storage media to insure high reliability, low power drain and light weight.



Ferranti ELECTRIC, INC. Light Equipment Division

BUFFER STORE



FEATURES

ASYNCHRONOUS

Input and output operate either asynchronously or are driven from an external or internal clock.

LOW POWER DRAIN

The unit uses less than 10 watts, 115 VAC.

INCREASABLE STORAGE

Modularized system provides the capability of increasing storage for future use.

STATUS DISPLAY

Indicators and logic states signify that buffer is "Empty", "90% Full" and "Full".

HIGH RELIABILITY

Internal clock and silicon transistors permit operation over an extreme temperature range.

INTERNAL TEST

Internal test permits a "bit by bit" data pattern to be inserted and read by the operator with indicator lights describing the message.

ECONOMY

Magnetostrictive delay lines are superior for buffering applications and offer greater economy and reliability than other methods.

APPLICATIONS

Rate Changing — The buffer store is applicable for use in computers and communications systems since it is basically a rate changing device. The input and output speed may operate from random access up to 2 megacycles NRZ. The memory section of the buffer, consisting of magnetostrictive delay lines, can be programmed from both internal and external logic stations.

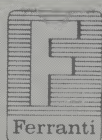
Multiplexing — Several pieces of low speed equipment may be multiplexed for use with one buffer, the output then feeding a high speed communication channel. This arrangement may also be utilized in reverse in which case several low speed readouts may be driven by one buffer.

Small Computer — The Ferranti Buffer can provide the basic memory for a small computer. The internal logic is modular in design and is capable of receiving external programming.

SPECIFICATIONS

Input ▲	Positive logic convention
Output ▲	Positive logic convention (Dry contact available)
Capacity ▲	5000 bits
Power required	115 VAC 50-60 cps, 10 watts
Environment ▲	Industrial
Size	14 x 14 x 6" (Cabinet or rack mounting)
Weight	Under 20 lbs.
Operating Mode ▲	Serial
Controls	"On-Off", "Clear", "Read-Out", "Test-Operate"

▲ Specifications may be varied upon request.



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BUFFER STORE

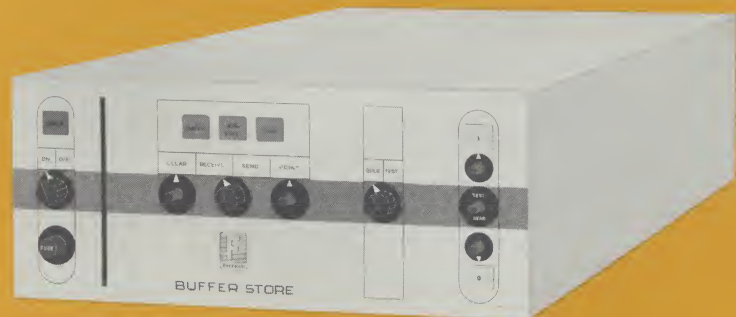
Ferranti

OPERATING MODE

serial or parallel input or output

READOUT

destructive or non-destructive



DESCRIPTION

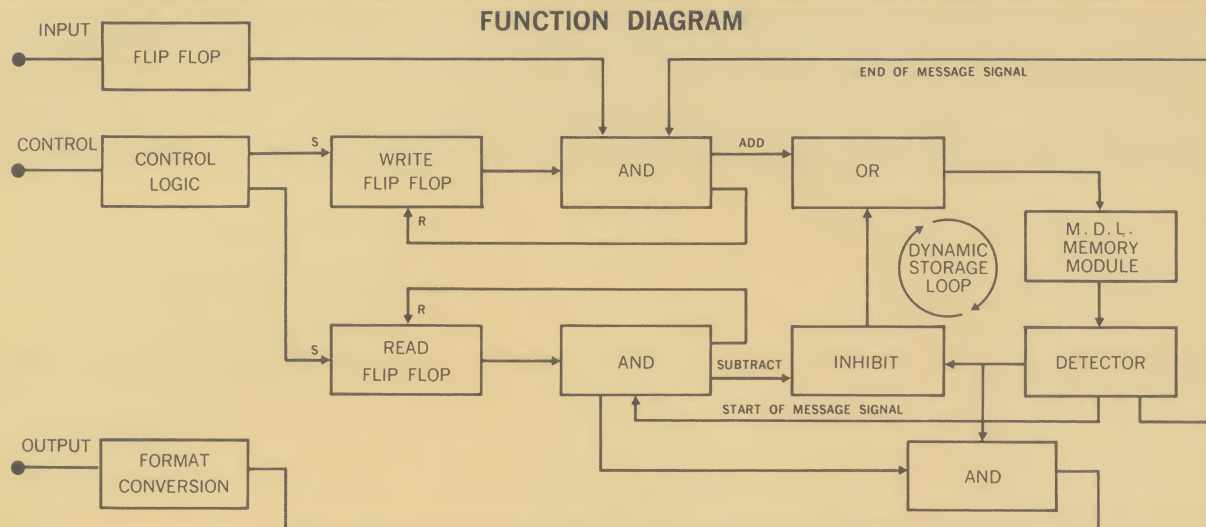
The Ferranti Buffer Store is intended for real time processing of digital information between two or more pieces of digital equipment operating at different time rates. Consequently it is compatible for use with most of the computers, magnetic tapes, paper tape readers, card readers, card punches, typewriters and Teletype machines in operation today. The unit is modularized permitting the storage capacity to be increased or decreased readily, thus affording the user the most economical

design. All logic and control functions are performed through silicon circuitry and are made compatible with germanium logic conventions through the use of auxiliary input and output conversions. A self-contained power supply, an internal test mode, and logic indicators provide for ease of operation with a minimum of personnel training. Magnetostrictive delay lines are utilized as the timing and storage media to insure high reliability, low power drain and light weight.



Ferranti ELECTRIC, INC. Light Equipment Division

BUFFER STORE



FEATURES

ASYNCHRONOUS

Input and output operate either asynchronously or are driven from an external or internal clock.

LOW POWER DRAIN

The unit uses less than 10 watts, 115 VAC.

INCREASABLE STORAGE

Modularized system provides the capability of increasing storage for future use.

STATUS DISPLAY

Indicators and logic states signify that buffer is "Empty", "90% Full" and "Full".

HIGH RELIABILITY

Internal clock and silicon transistors permit operation over an extreme temperature range.

INTERNAL TEST

Internal test permits a "bit by bit" data pattern to be inserted and read by the operator with indicator lights describing the message.

ECONOMY

Magnetostrictive delay lines are superior for buffering applications and offer greater economy and reliability than other methods.

APPLICATIONS

Rate Changing — The buffer store is applicable for use in computers and communications systems since it is basically a rate changing device. The input and output speed may operate from random access up to 2 megacycles NRZ. The memory section of the buffer, consisting of magnetostrictive delay lines, can be programmed from both internal and external logic stations.

Multiplexing — Several pieces of low speed equipment may be multiplexed for use with one buffer, the output then feeding a high speed communication channel. This arrangement may also be utilized in reverse in which case several low speed readouts may be driven by one buffer.

Small Computer — The Ferranti Buffer can provide the basic memory for a small computer. The internal logic is modular in design and is capable of receiving external programming.

SPECIFICATIONS

Input ▲	Positive logic convention
Output ▲	Positive logic convention (Dry contact available)
Capacity ▲	5000 bits
Power required	115 VAC 50-60 cps, 10 watts
Environment ▲	Industrial
Size	14 x 14 x 6" (Cabinet or rack mounting)
Weight	Under 20 lbs.
Operating Mode ▲	Serial
Controls	"On-Off", "Clear", "Read-Out", "Test-Operate"

▲ Specifications may be varied upon request.



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UNIVERSAL AMPLIFIERS

Ferranti



Model AL1015-5 (actual size)

FOR DELAY LINE OPERATIONS

in digital mode

DESCRIPTION

The AL1015 is a universal amplifier series developed to meet all the requirements necessary to operate magnetostrictive delay lines in a digital fashion. The unit is available in both a commercial and military version, qualified to meet MIL Standard 701. The circuitry uses silicon diodes and transistors throughout and operates entirely with a +12VDC power supply.

When the delay module is operated with negative polarity logic it is only required to add conversion stages to the input and output of the amplifier. These conversion cards are read-

ily available to specific requirements along with any necessary input or output logic gates.

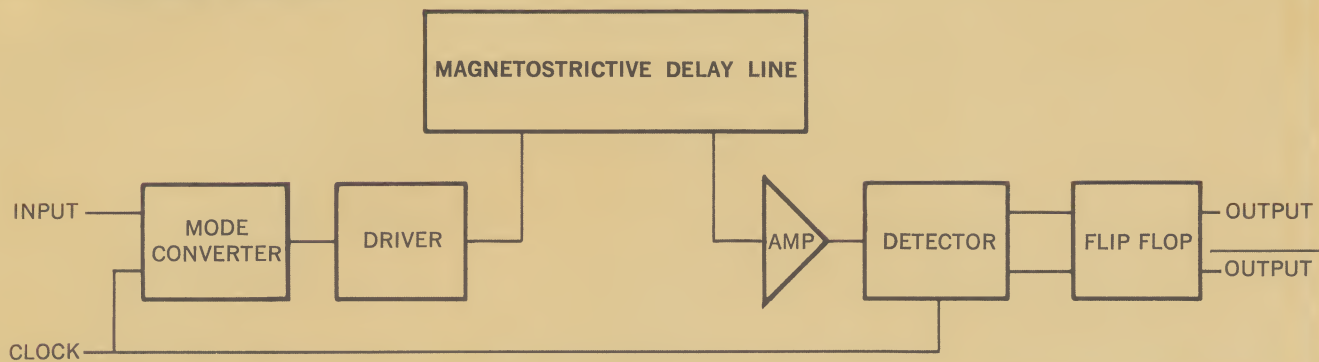
The Ferranti AL1015 series amplifier is designed to operate over the necessary gain-bandwidth conditions to be compatible with all magnetostrictive delay lines. All components dissipate less than 45% of their rating at 100°C in order to keep the mean time before failure high for the delay module. The amplifier is supplied with both solder lugs and connectors and is easily attached to the delay line for ready installation in buffers, memory units, communications equipment, displays and many other delay line applications.



Ferranti ELECTRIC, INC. Light Equipment Division

UNIVERSAL AMPLIFIERS

FUNCTION DIAGRAM



UNIVERSAL AMPLIFIER OPERATING MODES

MODEL No.	INPUT		OUTPUT		DELAY LINE	
	Mode	Clock	Mode	Clock	Mode	Max. Data Freq.
AL1015-1	NRZ	No	NRZ▲	No	NRZ	2 Mc
AL1015-2	NRZ	No	NRZ▲	Yes	NRZ	2 Mc
AL1015-3	NRZ	Yes	RZ	No	RZ	1 Mc
AL1015-4	NRZ	Yes	NRZ▲	Yes	RZ	1 Mc
AL1015-5	NRZ	Yes	NRZ▲	Yes	Bi-polar	1 Mc
AL1015-6	NRZ	Yes	RZ▲	Yes	Bi-polar	1 Mc
AL1015-7	RZ	No	RZ	No	RZ	1 Mc
AL1015-8	RZ	No	RZ	Yes	RZ	1 Mc
AL1015-9	RZ	Yes	RZ▲	Yes	Bi-polar	1 Mc
AL1015-10	RZ	No	NRZ▲	Yes	RZ	1 Mc
AL1015-11	RZ	Yes	NRZ▲	Yes	Bi-polar	1 Mc
AL1015-12	Ternary	Yes	Ternary	Yes	Ternary	1 Mc
	RZ		RZ			

▲ The complement is also available

SPECIFICATIONS

Power	+12 VDC $\pm 5\%$
Input Levels	"0" < 0.3v at 4ma "1" > 1.0v less than 1ma
Output Levels	"0" < 0.3v 10ma "1" > 1.0v less than 5 μ a
Temperature	Commercial 0° to 60°C Military -54° to 100°C
Environment	MIL-E-16500B MIL Std 701
Material	Silicon transistors and diodes throughout G-10 glass epoxy printed circuit board
Dimensions	3" x 4" x 1/2" high over all 2 5/8" x 3 5/8" mounting centers

ORDERING INFORMATION

When ordering a standard delay line amplifier module specify the line length in microseconds and/or style $\blacksquare$, amplifier group number and environment. A typical coded ordering number follows:

1000 - L-35 - AL1015 - 1 - C

Line length in μ sec

Commercial or Military

See Ferranti Magnetostrictive Delay Line catalog, or inquire for special delay line, mounting, etc.

See tabulation above

■ As per Ferranti Magnetostrictive Delay Line manual - available on request.

Although Ferranti has a large variety of stock sizes and shapes we recognize the fact that the user often prefers a custom design approach for his specific problems. We have increased our prototype facilities in order to provide rapid design and delivery of special delay line amplifiers and other logic modules.



Ferranti ELECTRIC, INC. Light Equipment Division
INDUSTRIAL PARK NO. 1 • PLAINVIEW, LONG ISLAND, NEW YORK
Telephone 516-WELLS-8-7500 • TWX 516-433-9160 • FAX PLAINVIEW, N. Y.

Communication Buffer and Retrieval System

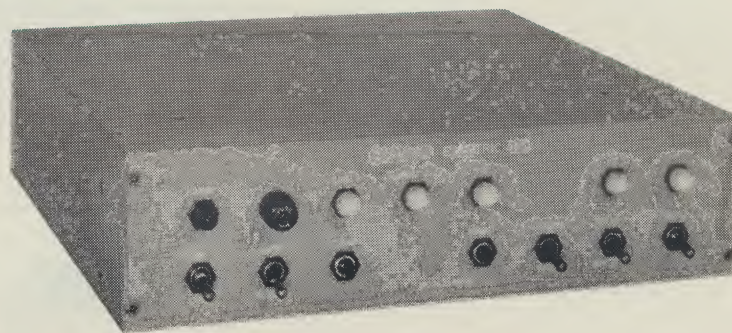


Fig. 1 Ferranti Electric's buffer store unit based on a recirculating magnetostrictive delay line.

Storage system utilizes advantages of magnetostrictive delay lines for sub-system applications in both computer and communication buffering.

For many data storage applications, magnetostrictive delay lines offer several advantages over other types of memory elements. These advantages include low cost per bit; low power consumption; noiseless operation; absence of moving parts; and simplicity of interface circuitry. The Ferranti buffer storage system, shown in Fig. 1, was developed in order to make use of these advantages in a practical, economical unit that can, with a minimum of special interface circuitry, be used as a sub-system in both computer and communication buffering applications.

As its memory element, this system uses a four millisecond magnetostrictive delay line operating at one megacycle in a recirculating mode, giving four thousand bits of storage. The system design is aimed at storing data for an indefinite time and then reading the bits out in the same sequence in which they are received. To accomplish this, the storage is itself sequential. This requires an ability to recognize the first and last bits in a message. In a binary system, this can only be done by cod-

ing or by utilizing a second memory to time the first one. For this system, it was decided to operate the delay line in a ternary mode, to obtain three separate logic levels: 0, 1, and no information. Time representation of the memory contents would then be as shown in Fig. 2.

The system design is further aimed at allowing input and output rates to be completely asynchronous. Lack of synchronism demands that the external circuitry tell the buffer when to write a "1", when to write a "0", and when to read a bit. Fig. 3 contains a block diagram of the input-output logic. Upon receiving a command to write a "1", the buffer logic does the following:

- Stores the "1" in a flip-flop.
- Stores the command to write in another flip-flop.
- Waits until it detects the presence of the first blank bit at the write transducer.
- Executes the command.

The freshly written bit then recirculates with the previously written in-

M. Ornstein, Project Engr.
Ferranti Electric, Inc.
Light Equipment Div.
Plainview, N.Y.

formation. For the special case where the buffer is empty, the command is executed without any waiting period. Upon receiving a command to "read a bit out", the buffer:

- stores the command in a flip-flop
- waits until it detects the presence of the first data bit at the output transducer
- sets an output flip-flop with the polarity of this first data bit
- erases this bit from the memory.

The only other requirement on timing of the external control signals is that they occur no more than once during each recirculation period of the delay line. If a particular system requires large memory capacity and short access time, this problem is overcome by the use of auxiliary buffering with fast access and low storage capacity. The auxiliary buffer can dump more than one bit at a time into

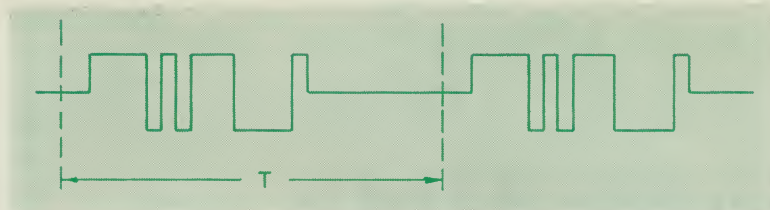


Fig. 2 Ternary Representation of Delay Information. The period T represents one recirculation time of the delay line. Note that, within T , the data occupies a solid block of memory space while the rest of the memory is blank.

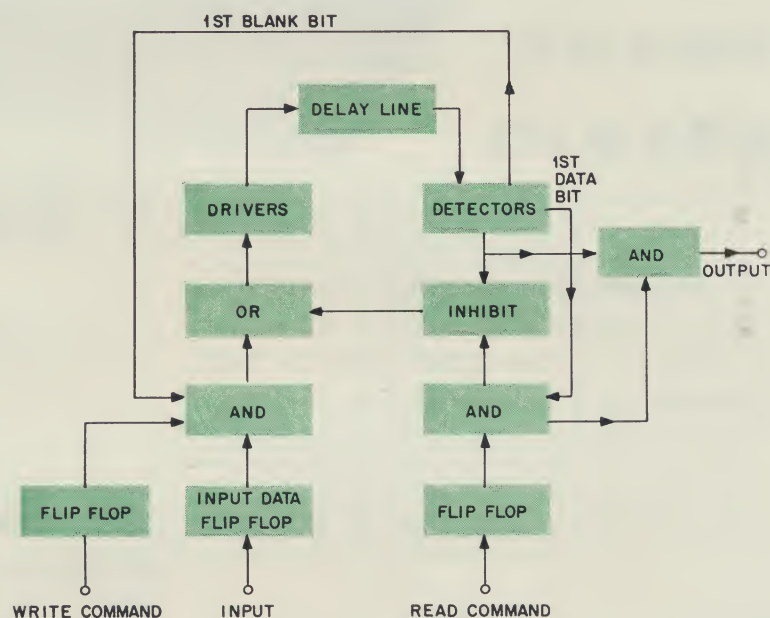


Fig. 3 Block diagram of buffer storage system.

the main buffer at a one megacycle rate. Other capabilities of this model are provision for external clearing of the buffer, and the ability to inhibit the input when the buffer is full.

In using this buffer in a practical system, it is necessary to decide how the external equipment will provide the control signals. An example of how this is done is by using a second model, Model 8002, which will extend the capabilities of Model 8001 to provide for storage and reprint of a message from a Model 35A Teletype machine. The Teletype sends and receives on a line which is asynchronous by character but synchronous within each character at a 9.04 millisecond bit rate. The line has a standby condition between characters and a start bit for each character which is of opposite polarity to the standby condition. Each character is 11 bits including the start and stop bits.

Model 8002 contains a multivibra-

tor with a 9.04 millisecond period and counter logic which causes the multivibrator to operate for 11 periods each time the input line senses a start bit. Each cycle of the multivibrator is interpreted by the buffer logic as a command to write-in the state of the input line at that time. When it is desired to print out a message, the multivibrator is caused to operate over the entire length of the message with the buffer logic interpreting each cycle as a read command. Non-destructive readout is accomplished by writing each bit at the end of the message during the same 9.04 millisecond period in which it was read out from the beginning. At the start of the cycle an end-of-message bit is included to stop the readout at the appropriate time. The special logic of the Model 8002 can be altered for other applications and requirements.

FERRANTI *Magnetostriction* DELAY LINES*

Are Reliable Components in
HIGH PERFORMANCE COMPUTER

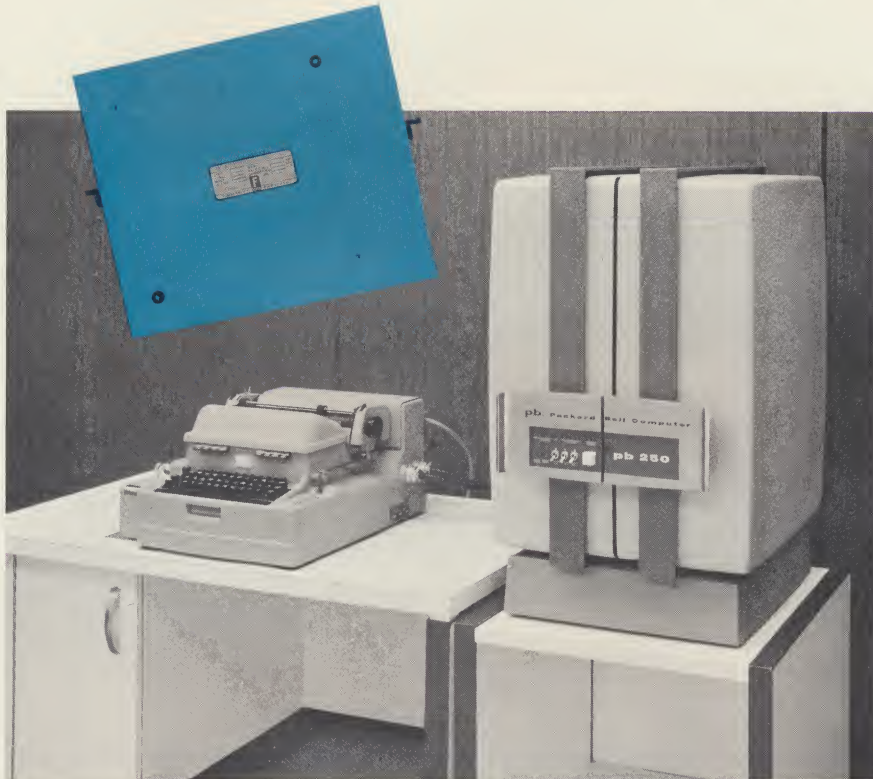
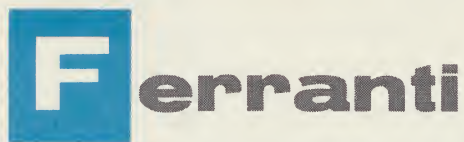


Photo Courtesy of Packard Bell Computer

A new, widely accepted and approved computer offering wide range flexibility and solid state reliability is the Type pb 250, designed and manufactured by Packard Bell Computer. This extremely compact and versatile computer offers new standards of precision and dependability, compatible with a new concept of low cost.

As an important component in achieving this reliability of function and speed, Packard Bell chose delay lines by Ferranti. The Ferranti Magnetostriction Delay Lines in this application feature a digit rate of 2Mc/s with delays up to 3071 microseconds (giving a storage capacity of 6142 bits). The temperature and amplitude characteristics are controlled to enable the computer to operate over its full temperature range without the use of ovens or other temperature control devices.

Write for detailed specifications



FERRANTI ELECTRIC, INC.

INDUSTRIAL PARK NO. 1 • PLAINVIEW, LONG ISLAND, N. Y.
Tel. 516 WElls 8-7500 • TWX HKVL 2381 • WUX LBI Plainview, N. Y.

*Manufactured under U.S. Patent No. 3,011,136.



MAGNETOSTRICTION DELAY LINE SPECIFICATION SHEET

Company Name: _____ Date: _____
Address: _____ Phone No: _____
Engineer: _____ Title: _____
Buyer's Name: _____
Application: ☐ Computer ☐ Radar ☐ Telemetry ☐ Other _____
Project No: _____
Quantity _____ Units: _____
Delay: _____ μ sec Max.
No. of Inputs: _____ : No. of Outputs _____ Delay Adj. Range $\pm$ _____ μ sec
Location of Taps: (refer to brochure for restrictions) _____ μ sec

OPERATING CONDITIONS:

INPUT

Pulse Width (w) _____ μ sec at 10% pt.
Rise Time _____ μ sec at 10-90% pts.
Delay Time _____
Voltage Available _____ volts
Current _____ ma
Impedance _____ ohms
Source Impedance _____ ohms
Pulse Repetition Rate _____ Cps Max.
Mode of Operation ☐ Non Return to Zero ☐ Return to Zero ☐ Bi-Polar

OUTPUT

Resolution (R) _____ μ sec
Pulse Width _____ μ sec at 50% pt.
Rise Time _____ μ sec at 10-90% pts.
Voltage (A) _____ Min. _____ Max.
Impedance _____ Ohms
Load Impedance _____ Ohms
Signal to Noise Ratio _____ ☐ Single Pulse ☐ Random Pulse Pattern

Do you require associated delay line circuitry ☐ Yes ☐ No? If yes, please specify available voltages to amplifiers, input signal characteristics, matching input load impedance, and delay line output amplifier output impedance.

ENVIRONMENTAL CONDITIONS:

Max. Delay Drift _____ μ sec Total From _____ $^{\circ}$ C to _____ $^{\circ}$ C
Applicable MIL Specs _____

OPERATING

Shock: _____
Vibration: _____
Humidity: _____
Temperature: _____
Altitude: _____

NON OPERATING

MECHANICAL DIMENSIONS:

Can a Standard Ferranti style be used — specify Style No. _____

if not complete section below.

Length _____ Width _____ Height _____ Weight _____

Mounting Dimensions: _____

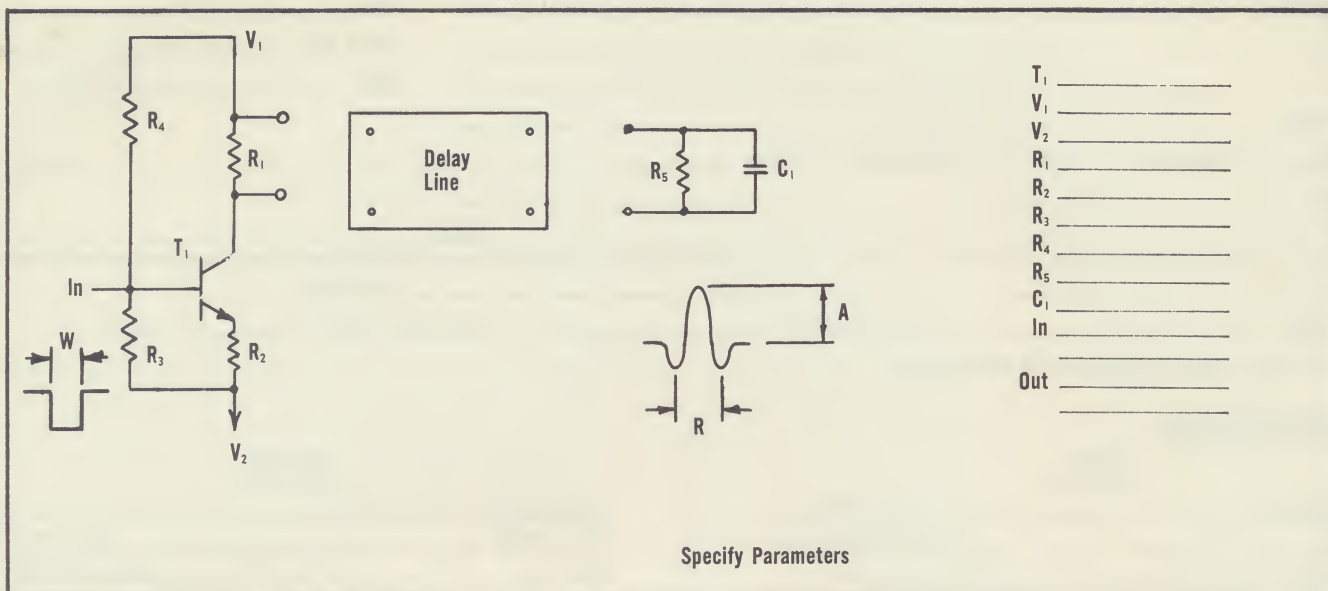
Type of Case ☐ Sealed ☐ Unsealed: Case Mat'l _____

Finish: _____

Attach sketches if necessary or use second side

Complete second side also

Test Circuit:

[illegible]

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Or your local Ferranti representative